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Validity and reliability of two field-based leg stiffness devices: implications for practical use

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Abstract

Leg stiffness is an important performance determinant in several sporting activities. The aim of this study was to evaluate the criterion-related validity and reliability of two field-based leg stiffness devices, Optojump Next® (Optojump) and Myotest Pro® (Myotest) in different testing approaches. Thirty-four males performed, on two separate sessions, three trials of 7 maximal hops, synchronously recorded from a force platform (FP), Optojump and Myotest. Validity (Pearson's correlation coefficient,r; relative mean bias, bias;, 95% limits of agreement, 95%LoA) and reliability (coefficient of variation, CV; standard error of measurement, SEM; intraclass correlation coefficient, ICC) were calculated for first attempt, maximal attempt, and average across three trials. For validity all three methods, Optojump correlated highly to the FP (range r = 0.98-0.99) with small bias (range 0.91-0.92, 95 LoA 0.86-0.98). Myotest demonstrated high correlation to FP (range r = 0.81-0.86) with large bias (range 1.92-1.93, 95% LoA 1.63-2.23).. In terms of reliability, Optojump yielded a low CV (range 5.9%-6.8%), SEM ranging 1.8-2.1 kN/m, and high ICC (range 0.82-0.86). Myotest had a larger CV (range 8.9%-13.0%), SEM ranging from 6.3-8.9 kN/m, and moderate ICC (range 0.64-0.79). The findings present important information for these devices and support the use of a single trial to assess leg stiffness in the field, thus testing in a time-efficient way.

Keywords: hopping test, vertical stiffness, test-retest, sensitivity.

Word Count: 3557

Introduction

Leg stiffness describes the response of the lower limbs to generate force and resist deformation during rebound activities.[8,9] Enhanced stiffness is beneficial to reduce metabolic cost of bouncing gait (i.e. running, hopping)[12-14] as well as to attaining high sprinting speed[15-16], whereas lower leg stiffness may lead to less storage and recoil of elastic energy, placing greater metabolic demand during push-off, and to a reduced ability to sustain impact loads, raising injury risk.[9,11,17] Thus, leg stiffness evaluation can be important both prior to and during training.

Two field-based devices can assess leg stiffness are the Optojump Next® (Microgate, Bolzano, Italy; Optojump) and Myotest Pro® (Myotest, Sion, Switzerland; Myotest).[21-22] Optojump Next® is an optical measurement system consisting of two infrared photocell bars that can derive contact and flight times from the breaking of the transmitted beam, whereas Myotest Pro® is a wireless lightweight portable triaxial accelerometer that can be fixed on the athlete. Both are portable and practical, allowing athletes to jump on any given surface, used largely because of their versatility and reasonable cost.[23-25]

Several studies have examined the devices' criterion-related validity and reliability for vertical jump height from squat and countermovement jumps in comparison to a force platform.[22,25-27] Leg stiffness with the above equipment, however, has either not been examined or has been conducted in a less time-efficient way. For example, in the Choukou et al[22] study, the authors processed the data obtained, thus determining the reliability of the processed data rather than the calculated value for Myotest Pro®, while substantially adding to the analysis time. Moreover, measurement reliability of the criterion-related leg stiffness outcome was not determined, raising uncertainty on interpretation of the results.

The aim of the present study was twofold. Criterion-related validity (the force platform as gold standard), reliability and sensitivity of both Optojump Next® and Myotest Pro® (henceforth Optojump and Myotest, respectively) for measuring leg stiffness in hopping was assessed, with no manipulation of the software, hardware or the data obtained, where possible. This approach was deemed to reflect more closely in the field testing conditions while provides realistic information for the equipment (i.e. when used as close to the manufacturer suggestions as possible). These aspects were then examined with three different procedures, namely the first trial executed, the average across three trials, and the maximal stiffness value out of them, to explore whether a single trial was sufficient, offering practical information in terms of timing requirements for leg stiffness testing.

Methods

Participants

Thirty-four male University students (age 21.8 ± 3.9 years, height 1.83 ± 0.07 m, body mass 79.0 ± 11.4 kg) took part in the study. They were all physically active, free from lower limbs injuries for at least six months prior to the testing sessions, and competing in various team sports. All participants were instructed to refrain from strenuous exercise, alcohol, and caffeine for 2 days, 24 and 2 hours before testing, respectively. Procedures were approved by the University Ethical Committee and informed consent was given by all participants.

Procedures

Participants visited the laboratory on two separate sessions, 1 week apart, at the same time of the day. The same protocol was strictly followed in each session. Following a standardised warm up, participants familiarised themselves with the test. All participants reported to be completely accustomed with the task, and no more than two familiarizing attempts were needed. Following a 5-minute rest, 3 trials of the 7MH were performed, with 2 minutes resting between trials. Participants were instructed to jump as high as possible, with minimal contact time, and with arms akimbo at all times. Hopping was chosen as well-documented functional task, and maximal effort was required as usually performed in field testing.

All jumps were performed on a force platform (FP) (AccuPower, AMTI, Watertown, MA, United States; 200 Hz sampling rate). The resulting vertical force-time trace allowed measuring participants' body mass, contact and flight times, used to calculate leg stiffness as = (mass x π(flight time + contact time))/ (contact time^2(((flight time + contact time)/π) – contact time/4)) (Eq. 1)[18]. Data was synchronously collected by Optojump and Myotest (Figure 1). Optojump 1 meter bars (resolution of 96 diodes, sampling rate of 1 kHz) were placed on the lateral border lines of FP. Contact and flight times for all seven jumps of 7MH test and the participant's body mass was used in Eq. 1 to calculate leg stiffness.[18] Myotest (sampling rate of 500 Hz) was fixed on the participants by means of an elastic Velcro waistband, fastened on a line passing on both great trochanters and the medium part of the gluteal region, as per manufacturer instructions. Myotest uses internal algorithms for calculation of leg stiffness taking into account the average of the best three hops from any given trial of 7MH. Leg stiffness values were displayed on the device screen immediately after the trial.

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Data Analysis

Leg stiffness was examined for all three devices from a) the 1st trial from each session (K_{First}), b) the average across three trials from session (K_{Avg}), and c) the maximal value from session (K_{Max}).

For the K_{Max} approach, Wilcoxon signed-rank test was used to check for conformity of the trial number wherein the maximum stiffness value occurred between each device and FP. No significant difference was revealed for any comparison. For the K_{Avg} approach, within-subject variation over the three trials was assessed via 1-way repeated measures ANOVA before averaging, reporting no significant differences. Therefore, stiffness results for each subject were collapsed to a single value per session.

Criterion-related validity assessment procedures

As no significant test-retest differences (examined with paired *t*-test) between Session 1 and Session 2 were reported for any of the equipment, results were collapsed to a single participant value for each of the K_{First} , K_{Max} , and K_{Avg} procedures.[28] These single values were then used to investigate for criterion-related validity of the Optojump and Myotest in comparison to the FP. Data was checked for heteroscedasticity by correlating the test score differences between either Optojump or Myotest and the FP to their mean value, for each procedure, following the method by Bland and Altman.[29] As significant correlations were found, indicating the presence of heteroscedasticity for the validity investigation, raw data was transformed using the natural logarithm before further analysis occurred.[29] Thereby, normality of residuals (log test score differences between either Optojump or Myotest and FP) was examined using the Shapiro-Wilk test, and with normality defined as the ratio of skewness and kurtosis to the respective standard error not exceeding ± 2.0.[30] Normal distribution was confirmed for each procedure and device. Criterion-related validity to the FP was assessed via Pearson's correlation coefficient and relative mean bias. In addition, as suggested by Bland & Altman[29], agreement between the measurement devices (either Optojump or Myotest related to FP) was examined, and 95% limits of agreement (95% LoA) were reported. The limits display that, for about 95% of cases, the leg stiffness measurement of the examined device may differ from the one of the FP by the lower limit to the upper limit. Pearson's correlation coefficient (r) was interpreted as indicating high correlation for an r value above 0.8.[31] Relative mean bias was calculated as the difference between the logarithmic transformed score means of either Optojump or Myotest and FP, and reported as antilog. Because the antilog of the difference between two logarithmic measurements equals to the dimensionless ratio between the same two measurements, the relative mean bias must be interpreted as the ratio between the average outcome of the examined device and that of the FP. Likewise, 95% LoA were calculated on the logarithmic scale, and reported as antilogs as mean difference ± 1.96 standard deviations of the differences.

Reliability assessment procedures

The residuals (raw 1st – 2nd session score differences) and the respective pair means for each piece of equipment and procedures were correlated, to investigate the presence of heteroscedasticity.[29] No significant correlation was found, indicating homoscedastic distribution. Thus, data was further analyzed as raw values. Normality of the residuals was then checked for both each procedure and device, and confirmed.

Indices of both absolute and relative reliability were used for the investigation, for each procedure. Absolute intersession reliability was assessed via coefficient of variation and standard error of measurement (CV and SEM, respectively). CV was calculated as the standard deviation (SD) divided by the mean and multiplied by 100 for each participant, and then averaged.[32] The threshold was set at 10%, with values below suggesting high consistency.[33,34] To better represent all individuals, SD of CV was also reported in addition to group mean CV.[33] SEM was calculated as the square root of the mean square error term in a repeated measures ANOVA.[30] SEM is of practical importance, as it allows coaches easily determine the minimum difference (MD) needed for a performance change to be considered real (95% confidence) rather than a measurement error[30,35], using the following formula:

$$MD = SEM \times 1.96 \times \sqrt{2} \quad \text{(Equation 2)}$$

Finally, relative intersession reliability was assessed by interclass correlation coefficient (ICC), calculated according to Hopkins[36] as:

$$1 - \left((SEM)^2/(\text{mean of subjects' standard deviation between trials})^2\right)$$

An ICC value above 0.8 was set as a threshold for indicating small measurement error.[37] Ninety-five per cent confidence intervals (95 % CI) for ICCs were also calculated using the spreadsheet provided by Hopkins[38], representing the likely range of values containing the true population of ICCs in approximately 95% of the cases.

Statistical significance level was set for each test at $P < 0.05$. All statistical tests were performed using SPSS software (IBM SPSS Statistics, version 20, Inc., Chicago, IL, USA).

Results

Leg stiffness calculated from Optojump (Table 1), demonstrated high correlation to FP leg stiffness (Table 1) in all analysis procedures (range r = 0.98-0.99, $P < .001$) with relative mean bias ranging from 0.91 to 0.92 (Table 2). 95%LoA (Table 2, Figure 2) were not substantially different between procedures. Leg stiffness calculated from Myotest (Table 1) also showed high correlation to FP leg stiffness in all methods (range r = 0.81 – 0.86, $P < .001$), with higher measured leg stiffness (relative bias ranging between 1.92 and 1.93, Table 2). 95%LoA reported were wider compared to Optojump (Table 2), evident from different y-axis ranges (Figure 2).

FP exhibited low CV, suggesting good absolute reliability (Table 3). However, when relative reliability was considered, only K_{Max} procedure reported an ICC ≥ 0.8, with K_{First} and K_{Avg} ICCs of 0.74 and 0.79, respectively. Optojump revealed high absolute and relative reliability in all three analysis procedures, shown from relatively low values of group mean CV and high

ICC (Table 3). For Myotest, the K_{Avg} procedure was the more consistent one with a low CV but moderate ICC, whereas K_{First} and K_{Max} reported lower consistency (Table 3). For all procedures, Myotest yielded higher SEM than FP and Optojump (Table 3).

Discussion

The aim of this study was to determine criterion-related validity and reliability of two commonly used field-based devices (i.e. Optojump and Myotest) in measuring leg stiffness. In addition, three different analysis procedures were examined (i.e. K_{First}, K_{Max} and K_{Avg}), to provide practical information in terms of timing requirements to assess leg stiffness. Optojump showed a valid leg stiffness measurement compared to FP, with all analysis procedures being reliable. Myotest also showed valid leg stiffness measurement compared to FP, but with moderate reliability for all three procedures.

Leg stiffness values measured with Optojump agreed well with the FP values and are within the range reported from previous literature.[10,18-20] When the three different procedures were considered, all three procedures showed high reliability, with similar indexes to earlier research using the FP.[39,40] The systematic bias of Optojump was most likely due to the placement of Optojump bars on the FP (Figure 1), meaning the infrared beams were 0.3 cm higher than the FP surface.[26] Consequently, increased contact time and reduced flight time compared to those of FP, resulted in lower leg stiffness.[4,18] Although this height discrepancy may appear as a methodological concern, we opted for this approach as it more closely reflects field testing, where the placement of the Optojump bars on a given surface (e.g. ground, court, track), will be included in the measurement.

Leg stiffness values obtained from Myotest were significantly different with the FP and outside the values seen from hopping in previous reports. [10,18-20] Further, reliability for all three procedures was moderate. Our results contradict the study by Choukou et al.,[22] who reported the 5 hop test as valid and reliable in measuring leg stiffness using Myotest [22]. The higher number of total hops considered in Choukou et al.[22] (all 5, compared to best 3 in the present investigation) could have reduced within-subject variability[36], possibly explaining the discrepancy. The overestimation of leg stiffness and poorer reliability of Myotest in relation to the FP might be attributed to the following reasons. Myotest leg stiffness computation is based on integration of acceleration, with respect to mass and time, and establishes the time interval of integration when the accelerations are null.[22] As maximal descending and ascending velocities are not achieved at those exact points, contact time and centre of mass displacement are underestimated, while flight time, force and jump height are overestimated[22,24]; in turn, magnifying leg stiffness values. Secondly, the fast transition between braking and push-off phase during the maximal hopping task is likely to have caused vibrations of the device and in turn erroneous acceleration detections. Indeed, previous comparisons of the Myotest against FP using single jumps (and, thus, little or no vibrations affecting the measurement) have reported better agreement.[27]

High sensitivity of a device allows for better determining differences resulting from true changes of the physical characteristic evaluated rather than from a measurement error.[35,42] For this purpose, we calculated SEM, to subsequently determine MD and construct confidence intervals, which can detect with reasonably good confidence (95%) real changes in the variable being measured. The importance of these confidence intervals for each device, the use of MD in assessing changes in performance, and of its magnitude in doing so with small changes can be better illustrated in the following example. Let us suppose that we tested an athlete who in the first testing session achieves a value of 25 kN/m. Following a training intervention, the athlete tests again and achieves a value of 33 kN/m. Replacing the Optojump and Myotest SEM from the

K_{First} procedure described in this paper (Tbale 3) in Eq. 2, the MD representing a true difference will be 5.8 kN/m for Optojump, and 21.1 kN/m for Myotest. As the test-retest difference (33 – 25 = 8 kN/m) lies outside the MD for Optojump, we would be certain (more than 95%) of a true change, whereas we would be unable to reach a conclusion using Myotest.

Assessing many athletes within the time-restrictions of a training or an assessment session, requires use of scientifically rigorous methods and consideration of the the practical aspects of the assessment (e.g. time availability, set-up and feedback time). Our results showed that leg stiffness assessment can be completed in a valid and reliable manner in the field, with minimal data manipulation (calculation of leg stiffness via Eq. 1). Further, leg stiffness can be confidently assessed with the use of a single trial, allowing time-efficient testing, in particular short time frames are available or large populations are to be tested.

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Tables

Table1. Leg stiffness (mean ± SD) for Session 1 and Session 2.

		Leg Stiffness (kN/m)	
		Session 1	**Session 2**
K_{First}	**FP**	26.3± 5.1	26.6± 5.6
	Optojump	24.2± 4.4	24.2 ± 5.1
	Myotest	53.0± 15.2	50.7± 14.0
K_{Avg}	**FP**	26.0± 5.2	26.2± 5.0
	Optojump	24.1 ± 4.6	23.9 ± 4.4
	Myotest	52.0 ± 14.3	50.2 ± 12.4
K_{Max}	**FP**	27.6± 5.6	27.6± 5.9
	Optojump	25.1± 4.7	24.8± 5.4
	Myotest	55.0± 15.1	51.8± 13.6

Note. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP).

Table 2. Criterion-related validity statistics, compared to FP.

		r	**Relative mean bias**	**95% LoA**
K_{First}	**Optojump**	0.99	0.91	0.86 – 0.96
	Myotest	0.82	1.93	1.63 – 2.23
K_{Avg}	**Optojump**	0.99	0.92	0.86 – 0.98
	Myotest	0.86	1.92	1.64 – 2.19
K_{Max}	**Optojump**	0.98	0.92	0.87-0.97
	Myotest	0.81	1.93	1.67 – 2.19

Note. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP); Pearson's product moment correlation coefficient (r); limits of agreement (LoA). All r values were statistically significant at the level of $P < .001$.

Table 3. Test-retest reliability statistics for every device

		CV ± SD (%)	**SEM (kN/m)**	**ICC (95% CI)**
K_{First}	**FP**	7.7 ± 7.5	2.8	0.74 (0.57 - 0.84)
	Optojump	6.6 ± 5.4	2.1	0.82 (0.70 – 0.90)
	Myotest	12.4 ± 7.0	7.6	0.74 (0.57 – 0.84)
K_{Avg}	**FP**	6.5 ± 7.7	2.4	0.79 (0.64 – 0.88)
	Optojump	5.9 ± 5.2	1.8	0.86 (0.74 – 0.92)
	Myotest	8.9 ± 7.1	6.3	0.79 (0.64 – 0.88)
K_{Max}	**FP**	7.3 ± 7.8	2.6	0.80 (0.66 – 0.88)
	Optojump	6.8 ± 6.7	2.1	0.83 (0.71 – 0.90)
	Myotest	13.0 ± 9.4	8.7	0.64 (0.44 – 0.78)

Note. First attempt procedure (K_{First}); maximal value procedure (K_{Max}); session average value procedure (K_{Avg}); force platform (FP); intraclass correlation coefficient (ICC); confidence intervals (CI); coefficient of variation (CV); standard deviation (SD); standard error of measurement (SEM).

Figure Captions

Figure 1. Experimental setup of the devices for synchronous data collection. Note that, custom-made wooden blocks were aligned behind and ahead of the force platform.

Figure 2. Limits of agreement. Ratio of leg stiffness measurements outcome between either Myotest (left side) or Optojump (right side) and Force platform (FP), plotted against their average. The continuous line represents the mean relative bias between the examined device and the FP. Dashed lines represents lower and upper limits with 95 % confidence. A) The 1st trial per session was considered (K_{First}). B) The average across the three trials per session was retained (K_{Avg}). C) The maximal stiffness value per session was considered (K_{Max}).